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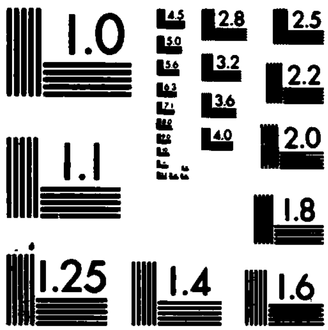
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DEVELOPMENT OF A DIGITAL MAPPING PROGRAM AT THE DEFENSE MAPPING AGENCY

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ABSTRACT

This paper discusses the development of a digital mapping program at the Defense Mapping Agency (DMA). The evolution of a conventional mapping production program from time consuming labor intensive processes into highly interactive and versatile operations is covered. Special emphasis is placed on the rationale for implementation of enhanced hardware and software technologies into the production processes.

INTRODUCTION

The Defense Mapping Agency was established in 1972 in order to unite all Department of Defense mapping functions into a coordinated program under a single authority. Inherent in the formation of a single agency was the idea that economies could be realized by streamlining production processes. DMA produces many different standard series of maps and charts. Basic photogrammetric and cartographic processes are used in the production of most of these products. Conventional production scenarios are labor intensive, error prone, costly and require from 6 to 24 months pipeline time to produce a map or chart from scratch. Such a manual program provides little flexibility and does not respond well to supporting the following requirements:

- New products
- Revisions to existing products
- Production line changes
- Out-of-cycle production

Automation of the mapping process is thus required to provide timely support of validated global needs. Early in its existence, DMA established a need for accurate up-to-date cartographic information in a digital format readily transformed to meet specific charting requirements. The automated mapping program had no sooner gotten started though, than requirements to supply digital data in weapon-specific formats forced DMA to divert the equipment it had procured for the charting programs to servicing the needs of the weapon systems. The digital data programs have, in fact, grown so rapidly that DMA is now required to devote over half of its production resources on digital products rather than on conventional mapping and charting.

The products that DMA produces are not the same types of products that are useful to cadastral surveyors, even though there is similarity in

nomenclature. To DMA, a large scale map is 1:50,000, or 1 cm equals 500 m. This is a far cry from the large scales used in cadastres, and the problems of production are different and varied; however, we do have several things in common. Since humans tend to learn from doing, perhaps someone just entering the field can learn from the experiences DMA has had, and avoid making a wrong turn here and there.

OBJECTIVES

Traditional color separation techniques for mapping include source evaluation and preparation, manual paneling, compilation, editing and negative engraving functions. These manual labor-intensive processes are prime candidates for computer assisted color-separation techniques. Objectives to be achieved are:

Increased productivity (less handling of data)
Standardization
Quick response to user needs
Cost savings
Increased flexibility

Computer assisted mapping does indeed have the potential to achieve these objectives. One should note, however, that cost savings can only be achieved through the maintenance (revision) process. The initial cost of the hardware is high and the transition of the information from the source materials to the digital data base often involves heavy computational loads and significant data processing support. The first time a digitally produced chart is made it will undoubtedly cost more than a conventional chart, even though efficiences are realized in the final stages of production. It is only after the digital data base is developed and implemented and the techniques for interactive maintenance of chart feature data establishd, that the paybacks inherent in a digital mapping program concept can be achieved. There is a protracted period after you have promised your boss that you will save money when you hope that you won't be required to justify your expenditures because all the ink is red.

COMPUTER ASSISTED MAPPING

An initial goal of the DMA auto carto program in the early 70's was to build a 1:50,000 scale digital data base using a then state-of-the-art manual line following collection system. A DEC PDP/15 minicomputer was the master processor for batch functions such as registration, transformation, paneling, and Input/Output, and it also supported a number of manual digitizer work stations for data collection. It was soon realized and verified that the goal of a 1:50,000 digital data base was then impractical with the available manual collection and processing technologies. Also, production priorities for the collection of elevation and feature data to support Air Force requirements for navigation and radar simulators completely took over the use of this digitizing equipment, and chart production was subsequently forced to remain in its conventional manual production mode. A digitizing system such as this line follower can be upgraded with additional processing power and its input capability can be enhanced with voice and scanning cursor technologies;

however, it still remains a line following system and such a system is efficient only for input of low density manuscripts. With the bulk of DMA source manuscripts containing large volumes of chart feature data, an alternative method of digitizing was required.

The implementation of reliable raster scanners in the late 1970's gave DMA the means to again actively pursue a digital mapping program. The collection of data from high density manuscripts was no longer the bottleneck as with the manual collection systems. High feature density manuscripts could now be digitized quickly, efficiently and accurately. The main drawback to this collection process was that the state-of-the-art for subsequent manipulation of the data was with vector technology. Thus additional processing resources were required for desymbolization of the raster input into line centered, segment node oriented type vector data suitable for support of software batch compilation functions such as projection transformation, scale changes, data merging, and the interactive maintenance (revision) of the digital charting data.

An additional bottleneck was that a cartographer/operator had to interactively redefine the attributes for the raster scanned chart feature data. Current raster to vector technology desymbolizes the collected data during the vectorizing processing and this required information is therefore lost. To recover this information, the operator has to put his graphic cursor on each chart feature segment and then interactively regenerate the header containing the desired attributes of the feature.

In effect, the raster scanner technology shifted the bottleneck from the collection phase to an interactive tagging operation. Thus, in order to obtain optimum performance for the collection of chart feature data, each source manuscript must be analyzed as to whether collection would be most efficient on a vector or raster collection system. As a general rule, higher density manuscripts should be collected via raster systems while low density manuscripts are probably more effectively input at a work station in a manual interactive mode.

Raster processing is also expensive in terms of data (pixel) processing and storage requirements. The source data usually requires additional preparation prior to collection. A monochrome scanner requires elimination of all background information which would be collected as noise. Additional batch processing and/or interactive editing by the operator would then be required to subsequently remove this noise. Source preparation for raster scanning is usually accomplished by preparing an overlay of the desired chart feature data for scanning. State-of-the-art color scanners which can scan up to 12 separate colors from a source manuscript in a single pass will potentially eliminate this problem. Still, the color scanner must be trained for each color to be collected. Color overprinting can subsequently cause breaks in the collected data which would again require additional software batch processing and/or interactive editing by a work station operator.

This highlights another problem for raster collection. For efficient scanning, the feature data must be continuous. If not, the gaps must be closed

by additional processing and/or operator intervention. Intermittent streams are a good example of this type of feature, where the symbol used is a pattern of dots and dashes. Everyone understands what the symbol means, but the scanner digitizes each separate segment as a different feature, and it is only through extensive editing techniques that we come out with the desired centerline data which can then be tagged with the attribute 'intermittent stream'. We don't want the savings in time gained by raster scanning to be lost through peripheral and additional work steps. Trends in advances of processing power, expert systems type software algorithms, and pattern analysis for feature recognition and identification of the raster scanned lineal data should minimize these problems within the next 4 to 6 years.

SYMBOLIZATION

The most visible effect of the digital mapping effort is in the reproduction of the manual negative engraving functions. The engraver uses specific scribing tools to generate the finishing symbology required for platemaking. If chart specifications require a road to be symbolized at a 10 mil line weight, the engraver would use a 10 mil point to generate the appropriate symbology. This function is readily adaptable to off-line software batch processing and subsequent output in plotter command formats to a photo finishing plotter.

Using properly tagged digital chart features data, the bulk of the manual scribing requirements can be eliminated. Tagging can be accomplished interactively by the operator at the work station. An identifing code is interactively attached to each chart feature segment. Within the processing software, the tag (ID) is referenced to a look-up table which contains the symbolization specifications required for the feature. The appropriate plotter commands are then generated for output to a finishing plotter. Thus 200 hours of manual engraving time could be logically replaced with a software program and the resulting photo plot. Engravers will continue to be required since the process is not yet completely automated and the software, in the near future, would definitely not be able to address the real time requirements for spot edits and displacement often required of the engraver at this stage of the production pipeline.

DMA has opted to utilize photo finishing plotters for the generation of the finishing plots suitable for platemaking. Scribe capabilities on the finishing plotters are available but are basically unused (at DMA) because of the efficiency, quality and speed of the photo option alternative.

TEXT

The placement of text is still basically a manual process at DMA; however, interactive text placement systems have been developed which can accurately place text over a composite copy (watercote) of the chart feature data. Also available are commercial interactive systems with which the operator can place text in the font desired. The bottleneck here is the nonavailability of a supporting digital data base of the chart feature data (all separations) and a digital data base of standardized geographic names for

display over the chart data for placement. Optical character recognition technology has the potential to support this requirement for input of our current card index file of geographic names into a digital geographic names data base.

CHARTING SUPPORT PROGRAMS

As mentioned previously, a tremendous amount of digital data will be required to allow us to realize the inherent benefits of a digital chart maintenance process. The ideal would be a product independent data base collected at a scale sufficient to support the largest scale product produced as well as all smaller scale products over the same geographic area. DMA currently has a number of programs which could feed such a digital data base in support of the charting program. Such programs include:

1. Feature Analysis Program: This is the collection of natural and man-made features with their respective attribute data. The program was started in support of the generation of simulated radar displays for use in trainers. For this use, the scale required, (1:250,000), was smaller than many of our maps, and many of the features shown on maps were not digitized since they were not important for simulating radar. We are in the process of redefining the specifications for this Digital Feature Analysis Data (DFAD) file so it will support not only radar displays, but mapping and charting and other weapon systems as well. The source of information is aerial photography supplemented by existing maps and charts. The imagery is viewed in stereo and photo-interpretation and mensuration are performed by the cartographer. This process has been extremely time consuming in both man- and machine-hours. We are currently developing a computer assisted photo-interpretation station to reduce the time required. With the input of additional information such as streams, bodies of water and lines of communication, the DFAD file could then directly support the mapping programs and be a source for satisfying medium and small scale charting requirements.

2. Terrain Elevation Program: The Digital Terrain Elevation Data (DTED) program generates regularly spaced elevation points from photogrammetric collection systems and can provide direct support to charting via the software generation of contour separations from the digital elevation grid. An added benefit is that the contours generated from photo source derived elevation grids tend to be more accurate than those compiled from cartographic sources. If we used only the regularly spaced elevation points, any plot would tend to cut off the tops of hills and fill in the valleys; to eliminate this effect, we also digitize ridge lines and valleys to define the extremes of elevations.

Production data generated in these programs is processed on DEC VAX 11/780 computers. Interactive graphic work stations allow editors to effect dynamic changes to the data. As stated before, these programs have the potential to support most digital charting requirements. Past efforts to integrate these efforts into a viable charting support production process have not been entirely successful for several reasons. In the past the charting, DTED and DFAD programs have been separate and legitimate programs. Each had its own requirment and production schedule. Hardware and manpower resources

were not available for efficient or practical exchange of data. Also, each program had the potential to use different sources and control. As a result, commonality problems could and did often result.

Typical DMA requirements for charting, DTED and DFAD could all be derived from the same basic control and source materials. Thus DMA is pursuing development of an advanced computer assisted photo interpretation system which would provide the capability to satisfy all requirements in a single pass. Such a system will produce common data elements, to the extent possible, in terms of cost and time availability, when digital data is required to support multiple products over the same geographic area. Such a system will capitalize on redundant production requirements, provide source and product commonality, and subsequently minimize a proliferation of production and maintenance software. We have now reached the point where our users are more interested in the accuracy available from photogrammetric processes than they are in having a certain chart updated from poor to marginal. We are now able to establish a comprehensive program that will lead to quality satisfaction of all requirements at minimum cost.

DMA is also investigating digital image processing in support of an all digital production system. Studies include interactive feature extraction and applied pattern recognition and are carried out on a digital image processing test bed delivered to DMA in 1981. This test bed system is equipped with image manipulation and graphics processing algorithms (including some pattern recognition schemes) to aid in detection/identification, classification, delineation and digital recording of feature data.

DIGITAL DATA BASE

DMA digital products have traditionally included a variety of product-specific data bases supporting the equipments and systems being developed by the various Armed Service organizations. This concept was viable until requirements began to outscope the resources available for producing the digital product. This has led to the requirement to produce a standard digital product which could service the needs of a variety of users. Even though our requirements for product-specific data will continue for many years, DMA is still actively pursuing the creation of a standard digital data base.

This proposed standard digital data base must be comprehensive enough to support not only our current requirements but also those that DMA's customers are now beginning to identify for the 1990's. Future digital data requirements will include new applications, better resolution, auto carto utilization, improved production methods, new formats, improved storage and handling and more sophisticated data base systems. Cost and time factors naturally prohibit the actual development of a separate data base to meet each need. Thus DMA is pursuing the development of a high resolution/terrain analysis data base and the use of a feature file concept to support future data base structures.

The feature file of any future data base should be a content oriented, format independent list of features designed to integrate the entire spectrum of digital data requirements. The type, size and accuracy of the features in

the file must all be designed to meet the most stringent user requirement. The use of a common format and appropriate transformation software will hopefully insure that the digital data base remains user transparent with the final output tailored to the specific requirement of each user.

SUMMARY

The rapid growth of computer assisted mapping is the natural result of advances in the following technologies:

Graphics:	resolution, color, zoom, roam, ...
Software developments:	transformation, rotation, perspective, three-dimensions, ...
Cartographic data bases:	data structures, transfer rates, storage capacities, costs, ...

The result is interactive mapping! Interactive mapping is the result of a marriage of the best of the manual and automated map production methodologies. We have the speed and accuracy of the computer combined with the cartographer's application of 'cartographic judgement' along with his capability to address non-sequential applications.

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